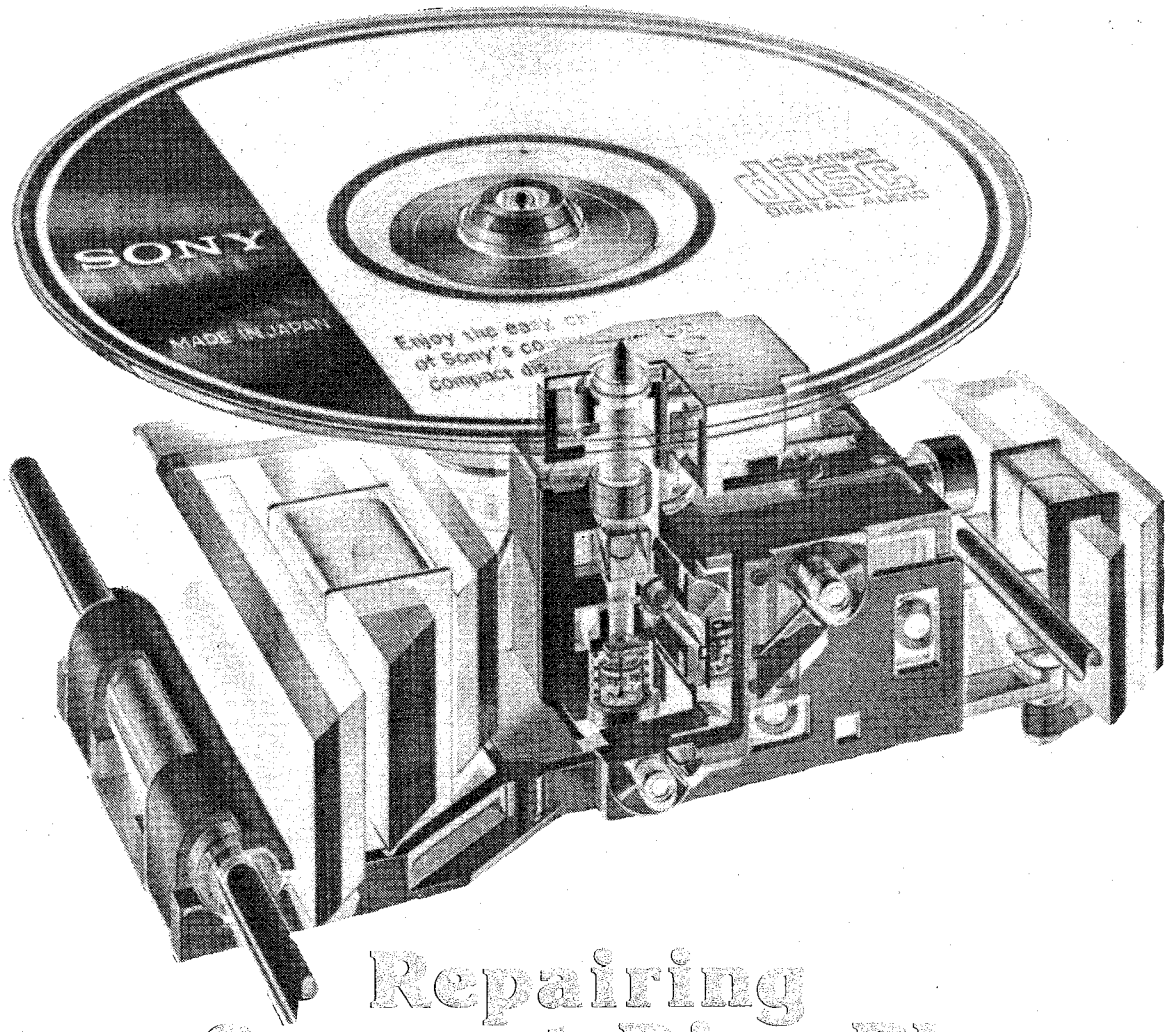

Repairing Compact Disc Players

Compact disc players are the most exciting development in audio in years. In this article we'll show you how those devices work, and how you can repair them when something goes wrong.

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COMPACT DISC (CD) SYSTEMS ARE SIMpler than VCR's and videodisc players, but they are still complex devices that require topnotch troubleshooting skills if they are to be successfully serviced. But if you have had some experience troubleshooting and repairing video or audio equipment, there's no reason not to try your hand at CD servicing.

Servicing CD players is not difficult, if you follow the procedures outlined in the manuals. Unfortunately, most such manuals assume that you are familiar with how a CD player operates. Because of that, little in the way of theory or background is provided. That is a shortcoming that this article aims to eliminate. By the time we are done, you will know the basics of CD-player operation, and repair.

CD player basics.

In this article we will cover CD players designed to reproduce sound from digital compact discs (digital CD's). The compact disc itself is single-sided, 4.75 inches (120 mm) in diameter, and can be used to store about 60 minutes of program information (in stereo). Just as with phonograph records, the program information on a CD may be music, speech, or any other type of audio. But such discs are not to be confused with conventional analog LP records, or with the so-called "digital" LP's. While in the manufacturing of digital LP's PCM (*P*ulse *C*ode *M*odulation) is used to record the original performance (PCM is also the recording technique in CD), the signal that is put on the LP record and played back at home is analog. The CD's described here are not interchangeable (electrically or physically) with analog LP records, digital PCM records, or videodiscs (even though the operating principles of videodisc players are quite similar to those of CD players).

Let's see how a CD player works. Figure 1 is a block diagram of a typical CD player. First off, unlike a phonograph record, a CD is "played" from the underside. The pickup used is not the familiar me-

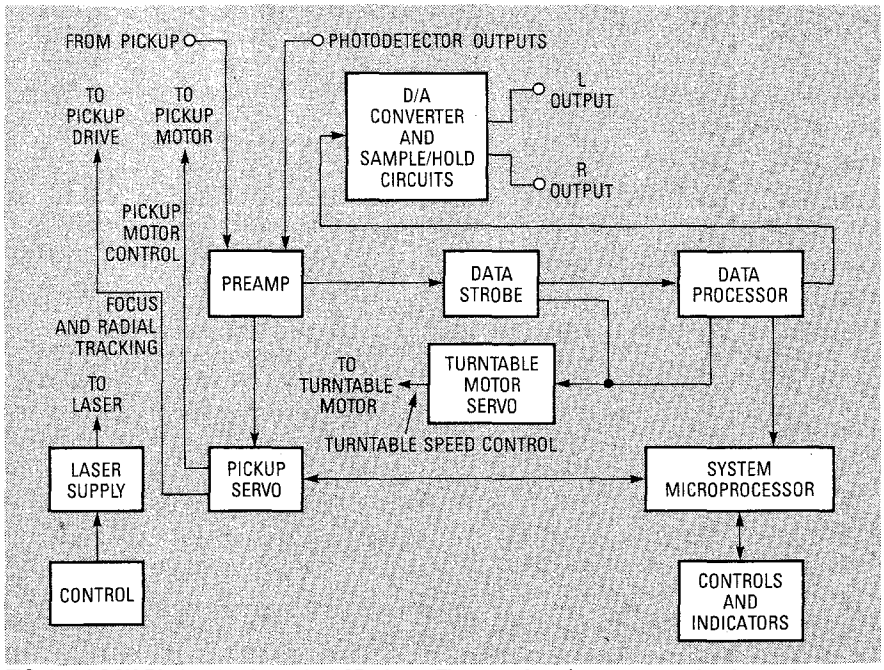

FIG. 1—BLOCK DIAGRAM of a typical CD player. The use of a microprocessor is what makes many convenience features possible.

chanical needle/stylus used in conventional phonographs, but rather an optical system that uses a light beam generated by a laser.

Another important difference is the manner in which information is recorded on a disc. The beginning of a CD "track" is near the center of the disc; as the program plays, the laser beam moves from the center of the disc to its outer edge. Also, rather than a groove, the information is recorded in the form of microscopic pits and flats. Those pits and flats are coded with music or other audio, as well as synchronization and identification information.

The light beam used in the CD optical pickup is focused on the CD surface by an objective lens. As the CD is played, the lens and beam are made to follow the track by a servo-operated pickup motor. The objective lens is part of a pickup assembly. There are two basic types of pickup assemblies, as shown in Fig. 2. In one, the optical system (including the objective lens) is mounted at the end of a rotating arm. The arm and lens are rotated (by the servo drive motor) so that the lens moves from disc center to edge. In the other configuration, the optical system is part of a slide assembly (also called the sled) that is motor driven.

While on the subject of motors, there is also a servo-operated turntable drive motor in all CD players (to spin the disc), and usually a loading motor (or possibly two) to insert and remove the disc from the player.

Although we have already pointed out that the method used in CD's to record information differs from that used in conventional phonograph records, perhaps we should point out the significance of that difference. Phonograph records store information in a continuous groove cut into the surface of the disc. The storage technique is analog; that is, the amplitude or depth of the groove is a direct representation of the audio signal. A conventional phonograph reproduces the audio signal via a mechanical pickup, called a needle or stylus, that detects the shape of the groove and is in direct physical contact with the surface of the disc.

On the other hand, the audio signals stored on a CD are in a high-density digital format. Further, a CD player's pickup never comes into physical contact with the disc surface. The first point means that the signal recorded on the disc is an extremely accurate representation of the original audio signal. The second point means that the problem of deteriorating sound quality over time, caused by the record wear that is unavoidable with a mechanical pick-up system, is eliminated. Also, mechanical pickup systems themselves introduce noise, such as clicks and pops, during playback; such noise is not generated by the CD playback system.

The laser beam is generated by a small low-power semiconductor diode made of aluminum-gallium-arsenide (AlGaAs). The laser beam is focused on the surface of the disc by the objective lens. That lens focuses the beam into a spot slightly less than 1 μm in diameter. Light is then reflected from the pits and flats back through the lens and optical system into infrared photodiodes. The signal from the photodiodes is used to reproduce the digitally-recorded information.

The groove on an LP record contains two signals—the stereo sum- and difference-signals—that must be simultaneously read and reproduced by conventional turntable pickup systems. The CD carries left and right channel information separately, but interlaces it on a single track. The nature of the information—that is, whether it is left or right channel, changes at fixed intervals. The player is programmed to keep step with those changes and thus maintains a high degree of isolation between the two audio channels. Realistically, channel separation of better than 90 dB is possible.

Signals are recorded in PCM form. During the recording process, the audio is sampled 44,100 times per second, (over twice the usual 20-kHz audio range). The composition (frequency, level, etc.) of each separate signal sample is then converted into a 16-bit (place) binary number. That process involves quantization. That is, the maximum signal amplitude is divided up into 2^{16} (65,536) gradations. The real level of the audio signal is then rounded to the nearest quantized value.

The use of the 16-bit system and the high sampling rate allows for an extremely accurate digital representation of the original analog signal. In theory, the dynamic range of the 16-bit system is almost 98 dB, although most CD manufacturers claim about a 90- to 95-dB dynamic range.

Figure 3-*a* shows a track of pits and flats. The length of the pits and flats determines the information contained on the track. The pits and flats can vary in length from about 1 to 3 μm. That variation in length is used to convey the information in the signal. Since the pits reflect less light than the flats, the CD player's optical pickup can differentiate between the two. Figure 3-*b* shows the analog signal that is recovered from the track shown in Fig. 3-*b*.

Optical pickup systems

Figure 4 shows the basic elements of the optical pickup (also called the optical readout) used by most slide-type CD players (the most popular type). The laser beam developed by the laser diode is applied to the reflective surface of the disc through an optical system (a series of lenses, prisms, gratings, and possibly mirrors). The beam is then reflected back through the optics to photodiode detectors (typically 6 diodes). The detector produces an output that corresponds to the audio stored on the disc, as well as tracking and focus signals.

In the system shown in Fig. 4 the disc spins in a horizontal plane. In many CD

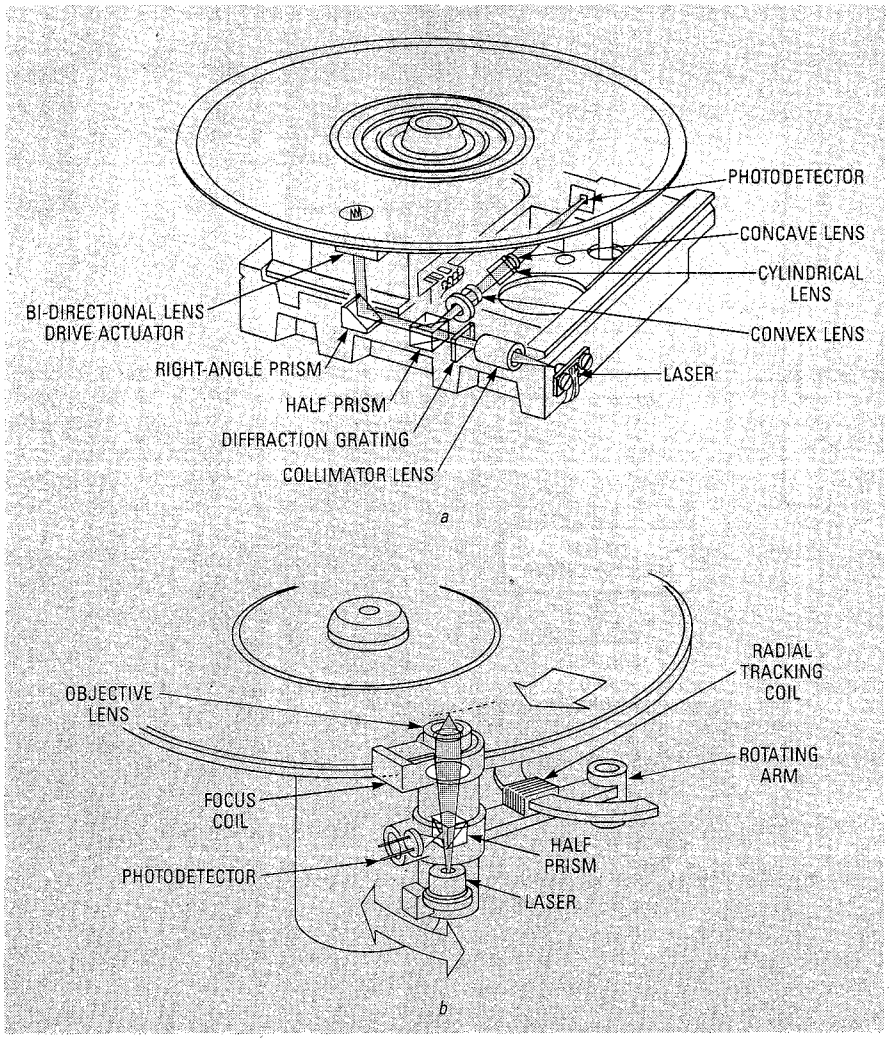

FIG. 2—CD PLAYER PICKUP SYSTEMS. Most CD players use either the slide (or sled) system shown in *a* or the rotating arm pickup shown in *b*.

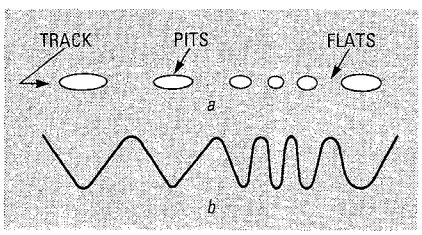

FIG. 3—THE LENGTHS OF the pits and flats (*a*) are used by the player to recover the original audio signal (*b*).

players, the disc spins vertically. Either way, it is essential that the laser beam follows the track of pits and flats as the optical pickup is drawn across the disc by the pickup motor, regardless of any possible disc eccentricity. That is called radial tracking, and usually involves a radial-tracking coil operated by a tracking servo to move the lens (and beam) as necessary.

The radial tracking system uses the 3-beam principle shown in Fig. 5. The 3-beam technique uses two sub-beams to detect tracking errors, and the main beam detects the audio signal. The sub-beams are produced by routing the laser beam through a glass diffraction grating, which creates several images on the same object. The two sub-beams are located ahead of and behind the main beam. After being reflected by the disc, each beam is routed through the optical system to corresponding photodetector diodes. The error signal from the two sub-beams is converted into an electrical signal, and then fed to an error-signal amplifier.

As long as disc tracking is precise, the error-signal amplifier output is zero. However, if even the slightest radial-tracking error is detected, the input differential between the two error signals (right and left) produces an output. That output is fed to the radial-tracking servo and coil; those move the objective lens (at right angles to the track) as necessary to correct the position of the main beam.

In rotating-arm systems, the radial tracking coil moves the entire arm and pickup as necessary to restore proper tracking. In most slide-type systems, the radial tracking coil moves the optical system (lenses, etc.) in relation to the remainder of the pickup assembly to restore tracking. A few players use a third system in which the tracking coil operates a rotary mirror placed between the laser and lens so that the beam is bent 90° when reflected by the mirror. The tracking signals cause the tracking coil to rotate the mirror (slightly) and direct the beam back to the track.

For service, it makes little difference which type of optical system is used since you must replace the entire pickup assembly as a package in the event of failure. Possible exceptions to that are the drive motor, drive belt, or a few gears. Optics are rarely replaceable, or even adjustable, in most CD players.

In addition to radial tracking, the optical pickup also provides for automatic focusing of the beam to compensate for vertical movement of the disc. The focusing system moves the objective lens (toward, or away from, the disc) if the laser beam is not focused precisely (within $\pm 1\mu m$) on the pits and flats.

Automatic focus (or AF) uses the astigmatism principle. In the simplest of terms, the main laser beam is detected by four equally-spaced photodiodes, shown in Fig. 6. (Those same diodes also reproduce the audio signal.) If the main beam is properly focused, the beam spot is round, and all four diodes receive the same amount of light (and output signals of the same strength). If the beam is not properly focused, the beam spot is elliptical, and the four diodes receive different amounts of light (and produce different outputs). The outputs from the four diodes are summed by an error amplifier; the output of that amplifier is the focus error. That error (if any) is fed to a focus coil or actuator that moves the objective lens as necessary to correct the focus.

Signal processing

The block diagram of Fig. 1 shows the sequence of signal processing within a typical CD. We will discuss each of those circuits later in this series. For now, let's quickly run through the sequence.

The photodiode output is very low, so it is first fed to a pre-amp where it is amplified. From there it is fed to a data strobe circuit that is used to differentiate between the logic-highs and logic-lows in the signal. The data strobe also extracts and separates the sync signals from the music and other audio. (Those sync signals are encoded along with the music at the time of disc manufacture; they make it possible for the CD player to reproduce audio at selected points on the disc track.)

The next stage is the data processor. That stage has many functions, including demodulation of the signal data, error detection and correction, and overall control of the signal processing circuit.

All CD player circuits include some provision for interleaving of signal data. When a CD is recorded, the music or other audio is interleaved before recording on the disc to provide error correction.

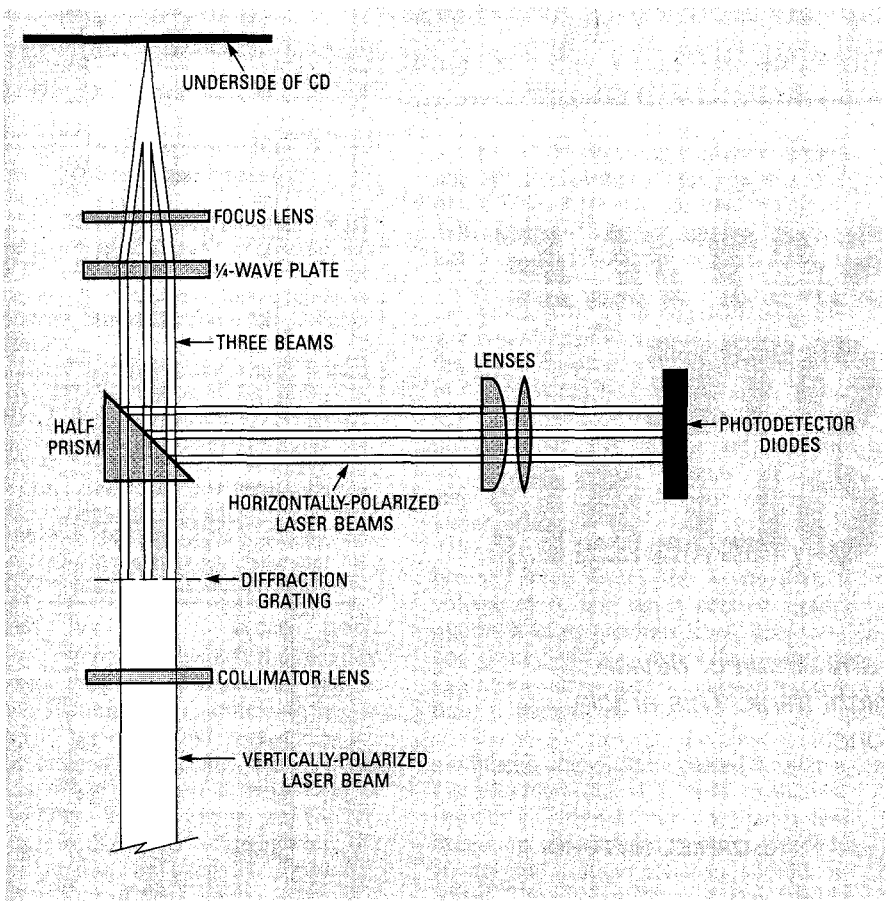

FIG. 4—BASIC ELEMENTS of a CD optical pickup system. In the system shown here the disc spins in a horizontal plane.

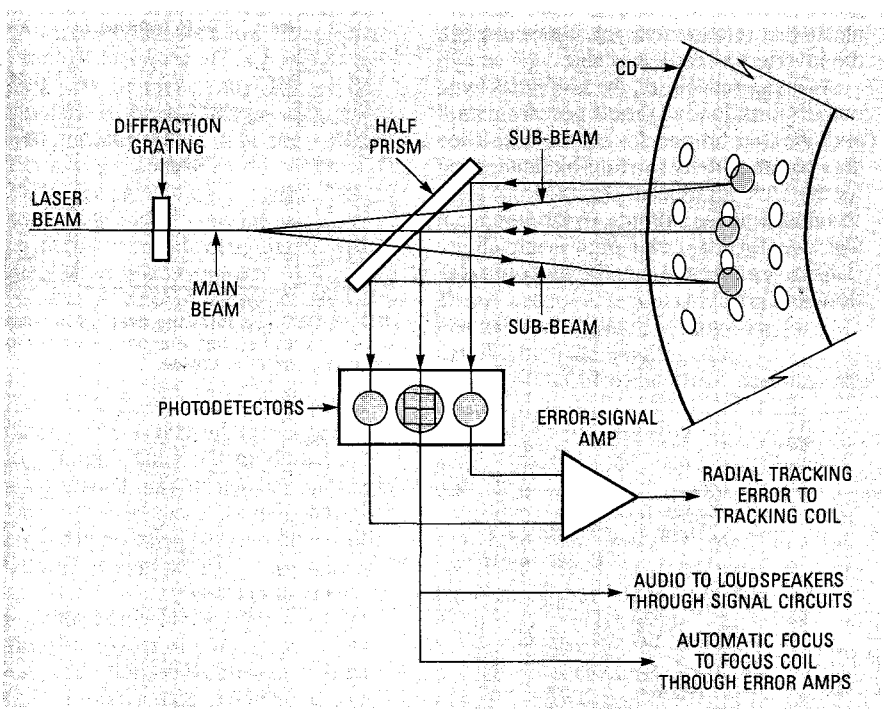

FIG. 5—A DIFFRACTION GRATING splits two sub-beams from the main laser beam. The sub-beams are used to make sure that the player is tracking properly.

The error correction method is called CIRC or *C*ross *I*nterleaved *R*eed-Solomon *C*ode, and involves both parity bits and interleaving. We will not go into CIRC here since that topic is beyond the scope of this article. But you must have some knowledge of interleaving to understand how a CD player works.

In the most basic of terms, interleaving involves dividing the audio to be recorded into a series of random sections, and then lining the sections in a new, fixed, order before recording. During playback, the

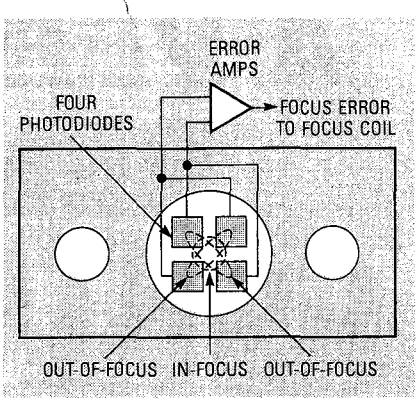

FIG. 6—FOUR PHOTODIODES are used to make sure that the beam is correctly focused.

sections are rearranged by the opposite process to recreate the original music or other signal. The playback arrangement processing is done by temporarily storing the data in RAM and then retrieving the data in the original order.

With interleaving, the effects of drop-outs in the audio (from any cause) are greatly minimized. That is true if even a relatively large part of the signal is lost. That's because such a loss is distributed over various smaller gaps in the recreated, final, audio signal. It is a relatively simple task for the digital signal-processing circuitry to "fill in" a small section of missing information when the data on either side of the gap is present.

The D/A converter follows the signal-processing circuits. The D/A converter transforms the digital signal back into an analog signal. The converted analog signal is then restored to pure two-channel audio by a sample-and-hold (S/H) circuit, and applied to the left and right stereo outputs.

Before we move on, let's look a little more closely at the D/A converter. Earlier we mentioned that the original audio is converted to 16-bit digital form for recording on a CD. Such discs, however, can be played back with almost no loss in dynamic range on players that use 14-bit D/A converters. The advantage of the use of such a converter, as opposed to a 16-bit converter, is cost. Thus you will find that many consumer CD players make use of 14-bit D/A converters.

Before one attempts to repair a CD player, it would be helpful to know how that player is supposed to operate in the first place. In the next part of this article we'll see how the various features and functions found on a typical CD player normally operate. **R-E**